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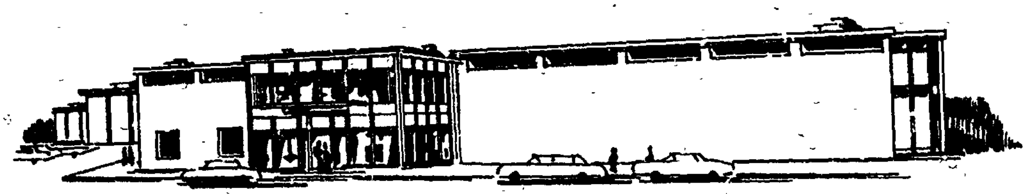

PUTTING TOMORROW'S MATERIALS TO WORK TODAY

G. T. SCHJELDAHL COMPANY
Northfield, Minnesota
13 November 1964

FINAL REPORT

FOR

CONTRACT NAS5-2834

Submitted To

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

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ABSTRACT

Contract 5-2834 as modified was directed toward establishing chemically milled aluminum-polypropylene laminates as suitable materials for use in communication satellites.

Under the contract, printing and chemical milling processes were refined. Experimental procedures for 20-inch wide material were reduced to production status of 54-inch wide webs. In laboratory studies copper chloride was found to be the best etchant for thick aluminum and precision milling. Four-mil thick aluminum was chemically milled to 90 per cent open area with little undercutting and excellent line definition.

In 50-day simulated space exposure tests it was demonstrated that polypropylene resists degradation more than Mylar and that "hot spot" temperatures for polypropylene will not exceed 15 C.

Free flight tests of an Echo I type balloon produced little data as the balloon overpressured rapidly and burst. No further tests were conducted.

Heat treating methods were developed which reduce shrinkage of aluminum-polypropylene laminates to as low as 2 per cent.

It is considered that the objectives of the contract were achieved.

Detailed discussions of the work performed under Modifications 1, 2, and 3 are not included in this report. For information on those efforts see the individual modification reports

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I. SUMMARY

Four major areas of study were considered under this contract. They include: (1) a fabrication program for large-scale spheres, (2) a study of the effects of space environment on the materials considered, (3) a free-flight atmospheric test of the Echo I and II type spheres so that radar reflectivity tests might be conducted, and (4) a study to explore the possibility of heat treating plastics so that shrinkage and other space environmental effects might be reduced.

Prior to this time, chemically milled material had been produced on an experimental basis in continuous lengths, but in widths of only 20 inches (Contract NAS5-1190). Under the present contract material production was reduced to production status of continuous lengths 54 inches wide. New techniques perfected include: (1) the simultaneous printing of both laminate surfaces so that the hexagonal patterns on each surface coincide, (2) high speed printing (100-125 feet per minute), and (3) continuous chemical milling of the laminate with removal of the etch resistant ink as part of the process. As a result, space quality material was produced which was suitable for large structures similar to the Echo II spacecraft.

Studies and experimental work were performed to determine the feasibility of using strain gages with this type material.

Baldwin Lima Hamilton SR-4, monofilament, nonsupported strain gages were found to be satisfactory since they have an extremely small diameter and are linear up to 20 per cent elongation. However, the gages are extremely delicate and also affect the immediate area of bonding. It was found that the two disadvantages could be overcome by careful handling and by calibrating the gages using an Instron tensile tester.

Two 135-foot diameter spheres were scheduled for fabrication after completion of material production. One sphere was to be used for a static inflation test, the other for folding, packing, and shake tests in a flight hardware canister. The two spheres were not constructed because NASA required additional study in the areas of space environmental effects and radar reflectivity. The latter work was then carried on under Modifications 1, 2, and 3 of NASA Contract NAS5-2834.

Under Modification 1 chemical milling runs were made evaluating various resists and etchants. A process was developed using a copper chloride etchant which will mill a 90 per cent open pattern in 4-mil aluminum. In addition, experiments were performed in a vacuum chamber solar simulator which indicate that both heat treatment and an initial exposure in a restrained condition improve the ability of polypropylene and Mylar to withstand the conditions of outer space.

Heat-treated Mylar exposed for 50 days shrunk 2.78 per cent after being given an initial radiation exposure in a restrained condition. Polypropylene retracted 4.4 per cent in the direction of restraint and considerably more in the lateral direction in which it was not initially restrained.

Thermal values were determined and theoretical balloon temperatures were calculated for materials that were exposed to solar radiation for 50 days. The results indicate that the optical degradation of polypropylene is much less than previously predicted. A hot spot temperature of 15 C was calculated for the polypropylene portion of a sample with a 90 per cent milled, 4-mil thick aluminum web. The calculated hot spot temperature for a similar material of Mylar was 84 C. These results indicate that a satellite constructed of polypropylene will not be damaged by overheating in an outer space environment.

The objective of the work performed under Modification 2 was to demonstrate the radar reflectivity versus skin stress relationship for Echo I and Echo II spheres by flying them as free-flight superpressure balloons to simulate the deployment and pressurization of the spheres under controlled conditions. Since the experiment was conducted with a short lead time and since the spheres had already been used in previous testing, there was some question that the Echo I sphere would reach the design altitude of 110,000 feet. However, the flight test was conducted.

The Echo I sphere was flown first to determine the launch and flight characteristics of the metalized spheres. It was hoped to obtain RF data which could be correlated with the performance of the orbiting Echo I. The flight indicated that excessive thermal heating due to absorption of solar energy by the metalized Mylar above the 40,000-foot altitude level resulted in an accelerating rate of ascent. The final rate of rise of Echo I at 110,000-foot altitude was 1,875 fpm or more than twice the 885 fpm rate of rise from launch to 40,000-foot altitude. The excessive rate of rise and resulting rapid pressurization rate (800 to 1,800 psi skin stress in one minute) are considered the major factors contributing to the balloon bursting at 2,000 psi skin stress level.

Changes in program requirements dictated cancellation of the Echo II flight.

The work performed under Modification 3 centered around the shrinkage characteristics of plastic films and plastic-aluminum laminations. The objective was to attempt a heat treating process such that subsequent exposure to a high temperature would not cause the material to shrink. Factors such as loss of mechanical properties, effects on thermodynamic properties, and the applicability of the process developed to production procedures were considered.

Heat treating methods have been developed to reduce shrinkage of polypropylene laminates to as low as 2 per cent (for a hot spot temperature of 100 C). The processes make fabrication of large spheres for satellite application possible.

The results of the test program indicate that Union Carbide biaxially oriented polypropylene is the best of the several materials tested, from the point of view of minimum shrinkage and maximum retention of basic material strength for any given heat treatment temperature. Heat treatment of Union Carbide polypropylene in a glycerine bath at 160 C for 1 minute provides the most economical heat treatment to obtain minimum shrinkage. Tensile strength of this material falls off rapidly at 165 or 170 C and heat treatment above 160 C is therefore, not recommended. Optical tests of the transmission of polypropylene indicate little variation between the untreated material and the treated material; therefore, the heat treatment technique does not seem to affect the average optical transmission properties of the polypropylene.

Glycerine, the heat treatment vehicle, is readily adaptable to presently available advanced material production equipment. It is an inexpensive, easily handled, non-hazardous, and non-toxic chemical and therefore, appears to be ideally suited for the heat treatment.

Rigidity test of cylinders show that heat treatment of the material does not affect the buckling strength of the laminate.

One highly important by-product of this study program has been the demonstration of the commercial feasibility of chemicall milling 90 per cent patterns in aluminum foil as thick as 4 mils. Precise milling of laminates using printed patterns has been demonstrated to be possible for lines as narrow as 0.004 inches and for a foil thickness of 0.002 inches.

Detailed discussions of the work performed under the three modifications to NASA Contract NAS5-2834 are not included as part of this report. For complete information on those efforts see: (1) "Final Report - The Effects of High Vacuum and Ultraviolet Radiation on Plastic Material", Modification 1 to NASA Contract NAS5-2834; (2) "Radar Reflectivity Tests of Echos I and II, Modification 2 to NASA Contract NAS5-2834; and (3) "Heat Stabilization Study of Advanced Materials", Modification 3 to NASA Contract NAS5-2834.

II. INTRODUCTION

The scope of Contract NAS5-2834 included the design, construction, testing and packing of two inflatable 135-foot diameter spheres. It was to include the materials and services required for these operations and a testing program to verify production methods as well as integrity of the spheres. It was also to include tests at the manufacturing plant and other test facilities as may have been required. It was further to include a static inflation test of sphere #1 and a packing test of sphere #2. Sphere #1 was to have been made from the plain chemically milled laminate material and sphere #2 was to have been made from a thermal coated chemically milled laminate material.

The overall objective of Contract NAS5-2834 was to verify production methods, reliability and packing with full-scale spheres using advanced materials and methods established under Contract NAS5-1190. The specific objectives were as follows:

1. Produce a continuous roll laminate composed of 0.45-mil thick polypropylene between two layers of 1145-0 aluminum foil 0.40-mil thick and 52 inches wide.
2. Print accurately a hexagonal pattern with 0.150-inch opening and 0.027-inch wide lines on both sides of the lamination in registration (± 0.010

inch) from front to back side with commercial printing equipment.

3. Conduct a static inflation test with sphere #1 to demonstrate fabrication accuracy and to determine the ultimate rupture pressure for future design purposes.

4. Demonstrate production chemical milling and cleaning operations to provide a milled laminate with a continuous aluminum pattern on both sides.

5. Demonstrate folding methods, canister packing and deployment tests as developed under Contract NAS5-1190 with sphere #2.

6. Conduct experiments to determine if packing methods were suitable for spin stabilization as might be required by Project Rebound.

7. Demonstrate inorganic coating (Alodine) on sphere #2 to provide necessary thermal values of absorptivity and emissivity.

Prior to this time, chemically milled material had been produced on an experimental basis in continuous lengths, but in widths of only 20 inches (Contract NAS5-1190). Under this contract material production was reduced to production status of continuous lengths 54 inches wide. New techniques perfected include: (1) the simultaneous printing of both laminate surfaces so that the hexagonal pattern on each surface coincide, (2) high speed printing (100-125 feet per minute), and (3) continuous chemical milling of the laminate with removal of the etch resistant ink as part of the process. As a result, space quality material was produced which was suitable for large structures similar to the Echo II spacecraft.

Studies and experimental work were performed to determine the feasibility of using strain gages with this type material. Baldwin Lima Hamilton SR-4, monofilament, nonsupported strain gages were found to be satisfactory since they have an extremely small diameter and are linear up to 20 per cent elongation. However, the gages are extremely delicate and also affect the immediate area of bonding. It was found that the two disadvantages could be overcome by careful handling and by calibrating the gages using an Instron tensile tester.

Two 135-foot diameter spheres were scheduled for fabrication after the completion of the preliminary work for material production. One sphere was to be used for a static inflation test, the other for folding, packing, and shake tests in a flight hardware canister. However, the two spheres were not constructed under this program because it was felt that some additional work was required in the areas of space environmental effects and radar reflectivity. The revised effort was then carried on under Modifications 1, 2, and 3 of NASA Contract NAS5-2834.

A. Modification One

Under Modification 1 chemical milling runs were made for the evaluation of various resists and etchants. In addition, experiments were performed in a simulated space environment. Both space vacuum (10^{-9} torr) and solar radiation were simulated.

Evaluation of continuous printing processes as used for flexible printed electronic circuits was made using several etch resists. Line definition and elimination of a thin film of resist from the aluminum were the major problems encountered when circuitry processes were applied to the aluminum-plastic lamination. Several resists were found suitable, but they did not withstand exposure to the caustic soda used to chemically mill aluminum. However, study and experimentation showed that copper chloride is an excellent etchant for aluminum and that the resists were not affected by the etchant. As a result, 4-mil thick aluminum was chemically milled to 90 per cent open area with little undercutting and excellent line definition.

Exploratory studies and 50-day tests in the simulated space environment indicate that both heat treatment and an initial exposure to space conditions in a restrained condition improve the ability of both Mylar and polypropylene to withstand the conditions of outer space.

Although heat treated Mylar showed no shrinkage for short exposures, under the conditions of the 50-day test it shrank 2.78 per cent. Samples of the same material which were placed in the chamber but which were not exposed to radiation shrank 0.33 per cent. However, exposure temperatures were higher than those anticipated in space. Therefore, less shrinkage and deterioration would occur with exposure to the space environment.

An exposure of 53 hours indicated that a 4-mil thick aluminum web was adequate to restrain polypropylene from shrinking, providing the material was adequately restrained during an initial radiation treatment. This was substantiated in the 50-day test. The material shrank about 4.4 per cent in the direction in which it was restrained but considerably more in the lateral unrestrained direction. However, only those portions of the sample that were under direct exposure exhibited shrinkage. The portions exposed to radiation filtering through the sample were not significantly affected.

Both tensile and optical properties were measured for the samples that were exposed for 50 days. The results indicate that the tensile strength of both Mylar and polypropylene dropped progressively as they were exposed to increasing amounts of radiation, but the optical degradation of polypropylene when exposed to solar radiation is much less than previously experienced under Contract NAS5-1190. Thermal values were determined and theoretical balloon temperatures were calculated for the materials; the mean effective radiant temperature and the hot spot temperature for polypropylene ran considerably lower than those for Mylar. A hot spot temperature of 15 C was calculated for the plastic portion of the polypropylene sample with a 4-mil thick aluminum web which was 90 per cent milled. The calculated hot spot temperature for a similar material of Mylar was 84 C. Based on calculated hot spot temperatures, a polypropylene balloon will not be damaged by overheating in the environment of outer space.

B. Modification Two

The second vertical test (AVT-2) of Project Echo A-12 was conducted at AMR with the purpose of flight qualifying the Echo balloon and its inflation system in an actual space environment. Prior to the test, the conclusion had been drawn, based on theoretical studies and limited scale model tests, that balloon surface imperfections would not impair the mission of the sphere as a passive communication device.

Radar cross section data, however, exhibited a pronounced scintillation with fluctuations of as much as 12 DB at S band and 8 DB at C band. Studies were made which indicated that the scintillations could be balloon dependent and that the periodicity could be correlated with balloon geometry, i.e. segmented construction of individual gores and seams. Therefore, it became necessary to attempt another means of demonstrating the relationship of radar reflectivity to the skin stress of the Echo II balloon.

Balloon free-flight tests of Echos I and II were designed as part of the work under Modification 2, to simulate the deployment and pressurizing of the spheres under controlled conditions. It was planned to reflect radar signals from the sphere in order to obtain more information on the effects of balloon skin stress on radar scintillation. Since the experiment was conducted with a short lead time and since the spheres had already been used in previous testing, there was some question that the Echo I sphere would reach the design altitude of 110,000 feet. However, the flight test was conducted. Each balloon was to be launched in the early morning from an area upwind from the White Sands Missile Range so that it would be over the Range when it reached ceiling altitude and was pressurized. The launch equipment was completely mobile so that a launch could be made from any suitable area dictated by wind condition. Launch sites could be changed as necessary up to 2-1/2 hours before launch time. The White Sands Missile Range personnel cooperated completely and under RFWAR 399 (Project Echo) provided radar and photographic coverage, meteorological services, helium, aircraft shuttle service, and other general assistance.

Instrumentation on the balloon was held to a minimum in order to reduce the weight and consequent deformations of the spherical shape. The Echo I balloon flight had one superpressure gage and a transmitter for telemetering the balloon superpressure back to the monitoring stations. Two superpressure gages and transmitters were planned for the Echo II flight. This duplication provided redundancy to the system. The only other instrumentation carried by the balloons was a timer-actuated destruct mechanism for termination of the flights.

C. Modification Three

The advantages of using an aluminum-polypropylene chemically milled lamination as compared to other aluminum-plastic laminations are: greater strength-to-weight ratio, and a lower effective modulus of elasticity. These two advantages lead to a lower weight sphere for a given diameter with higher relative rigidity and greater ease of packing relative to a sphere made of Echo II material. However, polypropylene has a tendency to shrink when exposed to heat. Such a tendency to shrink would cause distortions in a sphere and attendant degradation of the radio frequency reflecting characteristics of the sphere made from a chemically milled laminate. This is undesirable.

To eliminate or reduce the shrinkage in polypropylene film, attention to several factors in addition to simple shrinkage is required. That is, whatever technique is adopted for eliminating or reducing shrinkage must be feasible under production conditions. In addition, the shrinkage elimination techniques must not degrade the mechanical strength of the material nor the bond between the laminate and the polypropylene. Moreover, the infrared and solar transmittance of the polypropylene film should not be degraded to a point at which solar energy causes the material to reach thermal equilibrium at a high temperature, since this would cause the sphere to shrink excessively. This study program (Modification 3) investigated the shrinkage characteristics of polypropylene films and determined a shrinkage reduction technique for films and film laminates while simultaneously considering the factors mentioned. In addition, an analysis of the shrinkage of a sphere, buckling tests of cylinders and small spheres were conducted, and some Mylar shrinkage data have been presented.

Heat treating methods have been developed to reduce shrinkage of polypropylene laminates to as low as 2 per cent (for a hot spot temperature of 100 C). The results of the test program indicate that Union Carbide biaxially oriented polypropylene is the best from the point of view of minimum shrinkage and maximum retention of basic material strength for any given heat treatment temperature. Optical tests of the transmission of polypropylene indicate little variation between the untreated material and the treated material; therefore, the heat treatment technique does not seem to affect the average optical transmission properties of the polypropylene.

One highly important by-product of this study program has been the demonstration of the feasibility of chemically milling 90 per cent patterns in aluminum foil as thick as 4 mils. Precise milling of laminates using printed patterns has been demonstrated to be possible for lines as narrow as 0.004 inches and for a foil thickness of 0.002 inches.

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III. ENGINEERING AND TESTING

Engineering performed during the program concentrated on four main areas: (1) coordinating and scheduling production of materials, (2) preparation for a static test of sphere no. 1, (3) planning a packing test of sphere no. 2, and (4) thermal studies of coating materials for sphere no. 2. Engineering for material production and thermal studies is covered in Section IV and VI respectively.

Development of a bonded strain gage was a study effort conducted for the static inflation test. This was to improve the "state-of-the-art" for remote extensometer measurement on a large metal-plastic laminate balloon. Since it was desired to measure and record the strain on the 135-foot static inflation sphere an investigation of commercially available strain gages and special mounting techniques for this application was conducted. The gages tried were Baldwin Lima Hamilton models PA-3 and SR-4.

It was found that the SR-4 gages would yield accurate data when properly calibrated and compensated. Attachment and handling required considerable care since the gages were fragile and there was some hazard to the thin balloon skin during attachment, balloon handling, shipping and sphere inflation. This is generally true of any small rigid object attached to balloon material in a deflated condition.

The experimental data and description of the mounting experiments is covered in Monthly Report No. 1, 31 July 1962, under Section II, Engineering and Testing, description and data. A test with gages mounted on a 12.5-foot diameter sphere appears in Monthly Report No. 3, 1 October 1962 under Section II, Engineering and Testing.

The results of this work indicate that while it is feasible to obtain accurate data from these instruments there is a reduction of balloon reliability when they are attached prior to inflation.

A plan for a static inflation test was written and appears in Appendix A. This plan covers the objective, a complete description of the test, problems expected, precautions to be taken, materials necessary, design curves for the "flight" performance and temperature vs lift control of the balloon. The program was terminated before the static inflation test; therefore, no results are available. Considerable experience was later obtained from static inflation test of Echo II spheres in similar tests. These tests were performed under Contracts NAS5-3243 and NAS5-3522. Information is available in phase reports and final reports respectively.

Some drawings for the packing test of sphere no. 2 appear in Appendix B, but no specific test plan had been prepared. The packing method was to be as follows:

1. Accordion pleat the sphere concurrently with gore sealing.

2. Pleat with stiff templates to obtain definite-sized pleats which will result in a low-profile package after folding.

3. Place the pleated stack in a vinyl sleeve and evacuate the sleeve to compress the sphere. The vinyl sleeve would also serve as protection for the sphere during folding.

4. Fold the sphere with the aid of a folding jig while sleeved and evacuated to obtain a precisely folded stack.

5. After folding, remove the sleeve and lower the folds directly into the canister beneath the folding jig.

6. Place canister top half over folded stack and close with vacuumed plastic bag.

7. Check center of gravity and weight.

These methods incorporated those developed under Contract NAS5-1190. Since this test was not performed no results are available.

IV. MATERIAL PRODUCTION

Chemically milled aluminum polypropylene laminate materials similar to those developed and tested under Contract NAS5-1190 were in production under this contract. The material designated X-32-F was aluminum-plastic-aluminum bonded with GT-301 adhesive and was planned for use in sphere fabrication. The aluminum foil, Alcoa foil 1145-0 alloy 0.40-mil thick, was bonded to Union Carbide 0.45-mil biaxially oriented polypropylene. The aluminum foil was found to be of good quality with a low scrap rate. This thickness (0.40 mil) was relatively easy to produce even at 54 inches wide. The polypropylene was more difficult to produce since it was advancing the state-of-the-art in thin (0.45 mil) wide (60 inches) biaxially oriented film. Roll formation and web handling were the two most difficult problems encountered. An observation noted during incoming inspection of several lots of material was that roll formation improved on successive lots. It should also be noted that 60-inch wide material in this thickness had not previously been obtainable from any supplier.

A number of processing problems were encountered and solved during the various runs of material. During lamination web handling and roll formation problems were experienced resulting from the raw material problems. Generally, however, the quality of the material after lamination was quite uniform because the laminating rollers smoothed out irregularities and rough edges were easily trimmed once attached to the aluminum foil. Again, after some experience had been obtained the quality of material improved.

Early printing difficulties experienced were also associated with web handling and roll formation. Registration of the printing was complicated by machine misalinement, but was eventually overcome. Printing in register was achieved although considerable material loss was at first attributed to misregistration. A second set of printing rollers was prepared which were designed to overcome out-of-register problems, but were not used before the program terminated.

Chemical milling of wide (50 inches) material was demonstrated and proved successful as a continuous roll-to-roll process. A number of problems were encountered as covered in Weekly Report No. 7. These mainly were associated with machine performance during the first run. These were soon overcome and sufficient good material was run to permit the fabrication of 12.5-foot spheres and 5 gores for the 135-foot sphere no. 1. Following suspension of processing, recommendations were made to improve the process further for long sustained operations, but they were never carried out.

Processing specifications for the aforementioned operations appear in Appendix B. The material process briefly consists of the following steps:

1. Corona treatment - Center folded polypropylene is unfolded and passed through corona discharge machine to surface treat both plastic surfaces to improve adhesive bonds.
2. Lamination - Two layers of aluminum foil are bonded with adhesive to both sides of the polypropylene. A two-state process involving edge slitting and uniform roll rewinding after each step.
3. Printing - A hexagonal pattern is roller-printed with chemically resistant ink on both sides of the laminated material, registration of ± 0.01 inch required. This is a two-step single-stage operation.
4. Chemical milling - Immersion of the laminated printed material in an etchant bath to remove the exposed aluminum, then cleaning the resistive ink and exposed adhesive by immersion in an acid bath, and finally washing and drying of the milled material prior to rerolling for storage --a single-stage continuous web operation.

The results of material processing showed that it was feasible to produce an in-register chemically milled metal-plastic laminate and that with experience and equipment improvements the scrap rate could be reduced to a tolerable level.

A summary of the material processed follows:

1. Cut and accepted gores for fabrication - 5.
2. Laminated and printed material for chemical milling - 25,000 feet.
3. Laminated material for printing - 85,000 feet.
4. Polypropylene for corona treatment - 27,000 feet.
5. Aluminum foil for lamination - 80,000 feet.

These materials are at present in storage awaiting disposition.

V. SPHERE PRODUCTION

Fabrication of balloons was not started before termination of the program. The only progress in this area was laying and cutting of one group of gores and the building of model test spheres. The models were of identical design to that reported in the final report of NAS5-1190 except the X-32-F material was used. Figure 1 shows a 12.5-foot sphere inflated. As can be noted, the sphere was quite transparent because of the 72 per cent open area. This is in contrast to the spheres built with 68 per cent open area under Contract NAS5-1190. It was noted that the polypropylene used in X-32-F material was considerably clearer than that used with the earlier versions of X-32 material.

Some observations noted during the laying and cutting of gores are as follows:

1. No cast-off problems were encountered. The material was easy to make lay straight even in long lengths.
2. Blocking of the material was noted in rolls which were insufficiently dried after the washing stage. Tears resulted from the blocking during unrolling.
3. Small specks of resist ink were spread randomly on some areas of material. These specks also caused blocking. The residual ink resulted from improper chemical milling machine operation.

4. Out-of-registration areas were easily identified and rejected during gore laying.

5. All material from the first chemical milling run was laid for gore cutting. Total scrap due to all previous operations resulted in about 85 per cent loss through gore inspection.

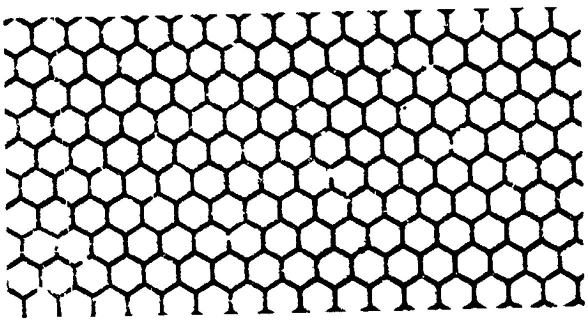
6. Cutting was accomplished with a fabric "Wolf" cutter. Cutting was smooth and uniform and no difficulties were encountered.

No further results were available since all fabrications operations were terminated.

Table of Physical Properties (Nominal Values)

	Machine Direction Direction	Transverse Direction
Tensile	13 lb/in	14 lb/in
Elongation	18%	20%
Weight	21.86 gm/sq yd	
Thermo shock	Excess of 10 flexures 10 cycles	

Sample of X-32-F



VI. THERMAL STUDIES (by Richard LaSell)

A. Thermal Balance Coatings

1. Alodine

Early in the program it was proposed to Alodine coat after laminating. This process would require the Alodine to withstand the effects of sulfuric acid used in the adhesive and resist removal step. An evaluation was made by soaking a sample of Alodine-coated aluminum in concentrated sulfuric acid for one minute. The results showed the solar absorption to be about the same with a decrease in infrared emission of 19.5 per cent. This indicated there should be no contact between the Alodine coat and the sulfuric acid bath.

It was found that the Alodine coating could best be applied as the final step in the following process:

1. Laminate
2. Print resist pattern
3. Chemically mill
4. Remove resist and adhesive
5. Alodine coat

The effect of Alodine on the polypropylene was studied to check the feasibility of the process.

Time Soaked in Alodine	Per Cent Solar Transmission	Per Cent Transmission at 60 C
Control	88.1	85.2
5 minutes	82.2	
1 hour	79.2	86.8

Since the actual process time in the Alodine bath is approximately 2 minutes the change in thermal properties is quite small.

Thermal values for Alodine coatings as determined by the Langley Research Center are listed in Table 1.

Coating weights of 183 to 188 mg/ft^2 of Alodine 401-45 tested by the G. T. Schjeldahl Company by a different technique yielded results of solar absorption of 32 per cent and 60 C emission of 17.3 to 20.3 per cent.

a. Polypropylene

Samples of three types of polypropylene were exposed to ultraviolet radiation and vacuum to determine the change in thermal properties with time.

1. Polypropylene "as received" plus corona treatment.
2. Polypropylene with ultraviolet stabilizers added.
3. Polypropylene "as received" laminated milled 100 per cent and adhesive removed.

Thermal checks were made periodically and the results are listed in Table 2.

TABLE 1

Alodine Thermal Characteristics*

Alodine 401-41

Surface Density mg/ft^2	Solar Absorption Per Cent	Temp. at Which Emission was Determined °C	Emission Per Cent**
30.4	33.1	-2	4.1
		48	4.65
		94	4.60
40.0	35.7	2.7	5.2
		57	5.9
		97	5.9
83.2	34.3	0	7.1
		44	8.2
		96	8.7
141.2	34.9	2	14.8
		47	15.8
		95	15.6
184	33.5	-2	15.9
		54	18.0
		96	18.1
300	34.7	-1	20.2
		50	26.2
		92	25.2
426	41.4	-2	50.6
		50	50.6
		93	50.5

* These values are from "Amorphous Phosphate Coatings for Thermal Control of Echo II" by Dewey L. Clemmons, Jr. and John D. Camp, NASA Langley Research Center.

**In general emission test values are only accurate to ± 11%.

TABLE 2

Polypropylene Exposure Test

Per Cent Solar Transmission

Sample*	Control	Exposure (days) 1	7	14	28	45	77
1	88.1	88.9	84.6	79.4	74.3	75.3	71.2
2	89.5	85.2	82.7	79.4	77.1	76.6	No value
3	84.0	75.2	78.2	72.2	73.1	73.1	69 2

Per Cent Transmission at 60 C

Sample*	Control	1	7	14	28	45	77
1	85.2	83.9	84.9				83.7
2	84.0	80.0	81.6				
3	82.2	81.9	83.0				82.9

*Note: Sample 1 - Polypropylene "as received"

Sample 2 - Polypropylene ultraviolet stabilized

Sample 3 - Polypropylene "as received", laminated, etched

b. Balloon Temperature

Balloon temperatures were calculated using the following parameters which are based on the Alodine values from Langley Research (Table 1) and the values for 62-day exposed polypropylene. The results are given in Table 3 and Figure 2.

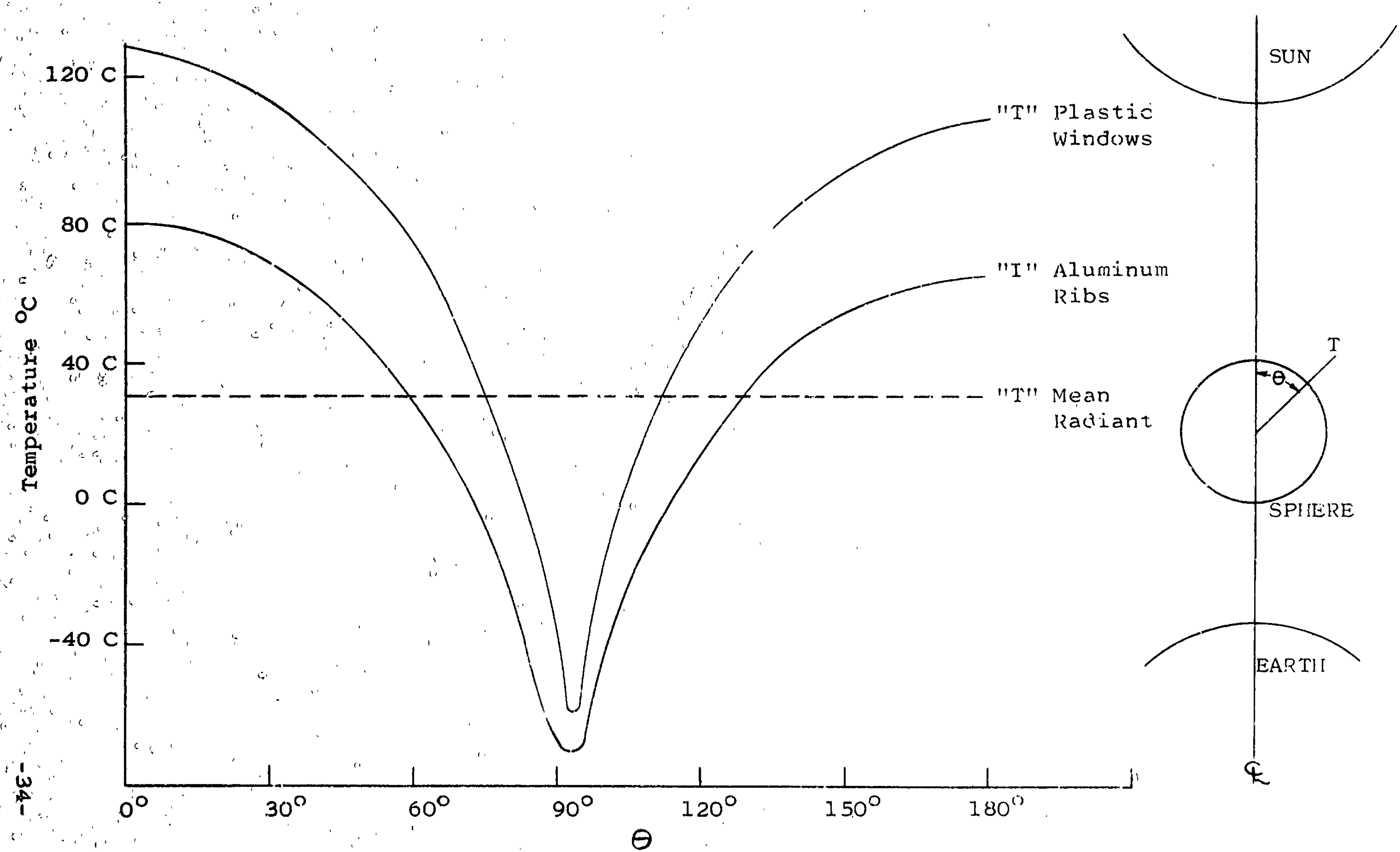
Polypropylene	0.6-mil, UDEL X-1; clear plastic exposed 62 days to U.V. radiation and vacuum.
Aluminum	0.4-mil; Alodine coated.
Albedo	0.55
Altitude	1700 miles
Attitude	In line
Solar Constant	1.353×10^6 erg/cm^2/sec
Fraction Aluminum	30 per cent
Reflected from Earth	0.6325×10^6 erg/cm^2/sec
Radiated from Earth	0.108×10^6 erg/cm^2/sec
Boltzman's Constant	5.67×10^{-5} erg/cm^2/sec/K^4
Polypropylene Properties:	
Solar Absorption	0.175
Infrared Emission	0.121
Solar Reflection	0.050
Infrared Reflection	0.050
Solar Transmission	0.775
Infrared Transmission	0.829
Aluminum Properties:	See Table I

TABLE 3

Balloon Temperatures

Sphere Calculation Number	I	II
Coat Thickness	134 mg/ft^2	300 mg/ft^2
Additional Weight (135-foot sphere)	12.8	21.2
Sphere in Line Between Earth and Sun		
Maximum Spot Temperature	113-130 C	99-110 C
Average Temperature	32-33 C	22-25 C
Maximum Spot Temperature on Patch		
Aluminum-Mylar Mylar inside	45 C	
Aluminum-Mylar Aluminum inside	273 C	
Aluminum-Mylar 300 mg/ft^2 Alodine coat outside	60 C	45 C
Aluminum-Mylar-Aluminum 300 mg/ft^2 Alodine coat both sides	110 C	
Aluminum-Mylar 184 mg/ft^2 Alodine coat inside	139 C	
Maximum Spot Temperature on Tape		
Aluminum-Plastic-Aluminum	135 C	
Aluminum-Plastic-Aluminum 184 mg/ft^2	119 C	121 C
Aluminum-Plastic-Aluminum 300 mg/ft^2	103 C	110 C

Figure 2. Temperature Gradient Around Sphere



2. Thermal Balance Ink

A study of paints as possible thermal balance coatings was made. They were found to require long drying times and add excessive weight to the balloon.

As a possible solution, the lighter weight, fast-drying thermal balance inks were studied next.

A search was undertaken to find an ink which would resist all the chemicals in both the milling and adhesiv removal process, and yet remain intact for a thermal balance coating.

The first inks that were tested showed inadequate resistance to the sulfuric acid used to remove the adhesive. The inks also appeared to discolor under exposure to ultraviolet radiation and vacuum.

Later in the program two inks formulated by the Marathon Paper Company were found to possess desirable properties.

Marathon No.	Pigment
EW 233	Anatase Titanium Dioxide
EW 234	Rutile Titanium Dioxide

These inks are very highly reflective throughout the spectral range checked and possess good acid and caustic resistance. The thermal values are listed in Table 4 with the exposure time. The thermal values appear to

TABLE 4

Thermal Balance Ink

Number	Caustic Resistance	Acid Resistance	Coating Density (gm/ft^2)	Unexposed Unprocessed			Exposed Unprocessed				Unexposed Processed		
				α	ε	α/ε	DAYS EXPOSED	α	ε	α/ε	α	ε	α/ε
34	Good	Bond Destroyed	0.280	0.183	0.023	7.98	23	.174	.042	4.14			
51	Very Poor	Very Poor	0.288	0.170	0.025	6.81	23	.207	.043	4.81			
233	Good	Good	0.211	0.200	0.022	9.09	30	.185	.075	2.47	0.207	0.199	1.04
234	Good	Good	0.196	.167	.028	5.96	30	.215	.058	3.7	.250	.288	.868
B26757	Very Poor	Very Poor	0.360				37	.188	.038	4.94			
B77412	Very Poor	Very Poor	0.460				24						

change drastically when processed in caustic and sulfuric acid. This change is for the better as far as this application is concerned.

An evaluation of the inks EW 233 and 234 was not completed due to the termination of the contract. It is suggested that any future investigation include the study of ink samples that have been both processed in caustic and sulfuric acid and exposed to simulated solar radiation.

Based on this very preliminary investigation however it appears that either of the inks EW 233 and 234 is a better thermal balance coating than Alodine.

The method of using ink would eliminate two problems. First, if the material is a better coating than Alodine it will tend to decrease the maximum temperature of the sphere and second, the change in thermal properties of the plastic observed due to exposure to Alodine would not occur.

Calculated balloon temperatures using ink EW 234 are listed in Table 5.

TABLE 5

Balloon Temperatures

(Thermal Balance Ink)

	Condition I	Condition II
Polypropylene	0.45-mil type 45-day exposure	0.6-mil type I 62 days exposure
Aluminum	Coated with No. 234 ink 196 mg/ft^2 processed unexposed	Coated with No. 234 ink 196 mg/ft^2 processed unexposed
Albedo	0.85	0.85
Altitude	1700 miles	1700 miles
Attitude	In line	In line
Fraction aluminum (%)	30	30
Polypropylene properties		
Solar absorption	0.220	0.175
Infrared emission	0.127	0.121
Solar reflection	0.050	0.050
Infrared reflection	0.050	0.050
Solar transmission	0.730	0.775
Infrared transmission	0.823	0.829
Aluminum properties		
Solar absorption	0.250	0.250
Infrared emission	0.228	0.228
Solar reflection	0.750	0.570
Infrared reflection	0.712	0.712
T mean effective radiant	60 C	44 C
T hot spot plastic	145 C	129 C
T hot spot aluminum	77 C	84 C

APPENDIX I

STATIC INFLATION TEST SCHEDULE

G. T. SCHJELDAHL COMPANY
Northfield, Minnesota
September, 1962

TEST SCHEDULE

STATIC INFLATION TESTS

PROJECT NGIS 135-FOOT DIAMETER SPHERE

LAKEHURST, NEW JERSEY

SUBMITTED TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

TABLE OF CONTENTS

1. Test Objectives

The objectives of this test are to determine 1) structural integrity of the laminate material, 2) effectiveness of the splice plate system, 3) ultimate burst pressure and related safety factor, 4) sphericity, and 5) quality of fabrication handling methods employed to produce the sphere.

This sphere will be identical in size and characteristics to the one intended for space flight except there will be no thermal coating on the surface and that it will be fitted with special test equipment to inflate and measure the performance of the sphere during pressurization tests.

2. Specific Tests

2.1 Structural Integrity

Structural integrity will be determined in two ways. First, strain gages located on the surface of the sphere will measure the surface strain versus internal pressure stress. Second, pressure will be measured throughout the test and the related stress will be calculated. The sphere will be pressurized in increments of 1,000 psi skin stress from zero to 4,000 psi, at which time it will be held for four hours for a seal creep test.

When the sphere has passed this test, it will be pressurized until it bursts and the ultimate stress point will be noted. By relating the final burst pressure to the designed operation pressure, a safety factor can be determined.

2.2 Splice Plate Integrity

Seam tests will be made by placing black ink marks across each splice plate at the equator and at points equidistant between the equator and the polar caps. If there is any adhesive creep or slippage, it will be shown by a gap or break in this black mark. These marks will be observed with a spotting scope during pressurization and measured after the burst test has been completed.

2.3 Sphericity

Sphericity will be obtained from circumference plots made with a theodolite. Photographs will be taken of the sphere at various pressure steps from various angles so that the dimensions can be compared with the scaling pylons located at either side of the sphere.

2.4 Electrical Conductivity

The electrical conductivity of the sphere will be checked by means of a wire conductor attached to the top end cap. A probe will then be placed on each gore near the bottom end cap to determine the electrical connection quality and the resistance of each gore.

2.5 Stress Areas and Deformations

Careful inspection of the sphere surface, gores and seals, will be made at intervals throughout the test. Any signs of stress areas and nonuniformity in the spherical surface will be recorded and photographed for evaluation. Some of these areas will be marked and removed from the balloon at the end of the test for further analysis if necessary. Observations will also be made of fabrication methods and handling procedures. Discrepancies of apparent handling damages will be noted so that corrective action can be taken.

2.6 Illumination to Show Transparency

Upon completion of inflation, the sphere will be illuminated with back and side lighting. Color photographs will then be made of the balloon in order to show the transparency of the chem-milled material. These photographs will be made at night to present a black background for the balloon.

2.7 Public Relation Photography

The Schjeldahl Company will take sequence 16-millimeter motion pictures of the entire operation. In addition, the Schjeldahl Company will provide still black and white picture coverage of each phase of sphere inflation and testing. It is anticipated that NASA and other groups will be interested in photographing the sphere at various stages and sufficient time will be allotted during the testing program for this purpose.

3. Time Schedule

The expected time to conduct this test will be three days; one day to prepare the test site and start setting up equipment, one day to complete set up, check instrumentation, lay out balloon and start inflation, one day to complete test and repack equipment for the return trip.

Due to the problems of temperature fluctuation that are experienced with the inflation test of the Echo A-12 balloon, the inflation will be started about 11 P. M. on the second day. It is expected to take about four hours to completely inflate the balloon, at which time the pressure tests will begin. It is expected that the pressure to burst test will be conducted by 11 A. M. This should take about one-half to one hour, at which time all the instrumentation will be repacked, final data gathered from the remnants of the burst balloon, and the test terminated.

4. Influence of Balloon Weight

The sphere, which weighs approximately 350 pounds, will, if uncompensated for, distort the balloon when it rests on the hangar floor. This distortion could considerably influence stress configurations over the sphere surface and therefore result in early balloon failure. An inflation method successfully used on the Echo A-12 static inflation test incorporated a mixture of helium and air. This same method will be used to inflate the balloon and suspend it just off the hangar floor so that the weight of the balloon will not distort the base of the balloon during the test.

5. Temperature Effect on the Balloon Lift

Due to the large volume of this balloon (approximately 1.3 million cubic feet) very slight changes in the balloon superheat will considerably affect the lift. As can be seen on the attached graph, a 5 F superheat in the sphere will result in approximately 900 pounds of lift. Temperature data taken from the hangar over a 24-hour period indicates as much as $\pm$ 15 F fluctuation from day to night. The balloon will tend to follow the air temperature, but some lag is inevitable. As a result, it has been decided to start the inflation about 11 P. M. so that the temperature change will be relatively stable during the next six hours. Then, if the test is conducted through a relatively stable condition until sunrise, minimum temperature fluctuation will result. At sunrise the ambient air temperature will begin to rise and there will be resulting lag in the temperature rise within the balloon. The temperature of the balloon will probably be lower than the temperature of the surrounding area, and the balloon will become heavy during this period. Special precautions to hold the balloon if it becomes light have been provided by attaching 15 hold down patches and lines around the circumference of the balloon as well as a net hung above the balloon on the hangar ceiling. The net will be used if the balloon cannot be contained with the hold down lines. In addition, carbon dioxide will be available to cool the internal gas and add weight to the system.

After sunrise, the balloon will start to grow heavier, and at this time more helium can be added to the balloon to offset the increasing weight and maintain a spherical shape.

Two 48-inch diameter inflation ducts will be attached at different levels from the base of the balloon in order that excess pressure can adequately be valved off in the event that the balloon does become heavier faster than more helium can be added. One duct will be more than adequate (based on A-12 sphere) to control the pressure of the balloon.

6. Inflation System

The balloon will be fitted with two polyethylene inflation tubes which extend about half way inside the balloon. The tubes will have nylon diffusers on them to prevent flutter produced from adding air to the light plastic balloon skin. A controllable 13,000 cfm fan will be used to pump the air-helium mixture into the balloon. Helium will be added at a point just beyond the inflation fan for adequate mixing of the helium and the air as it goes through the inflation tube and diffuser. This inflation method has been used successfully and there are no problems anticipated.

7. Instrumentation

7.1 Pressure measurements will be made by two magnehelic gages having a range of 0 to 0.5 inches of water and the other from 0 to 1.0 inch of water. In addition, two inclinometers having a range of 0 to 2.0 inches of water will be used.

7.2 Temperature Measurements

The G. T. Schjeldahl Company will supply thermocouples to be placed at the top and the base of the balloon. Provisions will be made to monitor these temperatures throughout the test. Ambient temperature at the top and base of the balloon will also be measured.

7.3 Photographic Coverage to Measure Sphericity

Two pylons 10 feet high and marked in one foot increments will be placed on either side of the balloon to permit scaling of the balloon diameter from enlarged photographs.

7.4 Sphericity Measurements

A tripod-mounted theodolite will be placed at the far end of the hangar for measurement of the balloon's periphery to determine sphericity.

7.5 Barometric Pressure

A mercury barometer will be used to measure the ambient pressure throughout the experiment to forewarn of any drastic weather changes which would affect the pressure of the balloon.

7.6 Strain Gage Measurements

Instrumentation which will scan all strain gages in sequence will provide records of the sphere skin strain.

8. Design Analysis

In order to avoid unforeseen difficulties in the execution of this test, the following design analysis as an experimental test will be made.

8.1 Blower capacity through inflation tube and diffuser

8.2 Adequate valving area in case of temperature and barometric pressure changes occuring during the period of the test

8.3 Error analysis and calibration of pressure measuring gages

8.4 Skin stress analysis of the tie points and attached testing gear

8.5 Accuracy of stress-strain measuring gages

8.6 Resistance in leads and couplings for measuring gore conductivity, lighting and clearance for proper photographic coverage

9. Test Equipment and Materials

The following is a list of test equipment and materials necessary for the inflation test.

9.1 A 135-foot diameter X-32-F material inflatable sphere with the following attachments:

a. Two 48-inch ducts, inflation GT-10 material

b. One 6-inch diameter S-10 material pressure tap tube with five valves

c. 15 tie down patches with tie down lines

d. 24 bonded wire strain gages with wiring harness

e. 220-foot continuity wire

f. Thermocouple attachment with lead out wire

g. Two inflation tubes with diffuser

9.2 Low resistance ohmeter 0.001 - 10 ohms

9.3 Three thermometers 0 - 50 C

9.4 Magnehelic pressure gages: 0 to 0.5 inch to 0 to 1 inch H_2O

9.5 Inclined monometer: 0 to 2.0 inch H_2O

9.6 Potentiometer for thermocouple read-out with switch

9.7 24-hour clock

9.8 Pitot tube and gage to check inflation time

9.9 Mercury barometer

9.10 Theodolite

9.11 Strain gage read-out instrument

9.12 Binoculars

9.13 Spotting scope

9.14 Spot light with batteries

9.15 Rubber hose for gages (0.5-inch I.D. and 0.375-inch I.D.) 50 feet

9.16 13,000 cfm fan (220 V 3 phase) (one)

9.17 Spare inflation tube with diffusers (one)

9.18 Flexible ballast chain (15)

9.19 10-foot long, one-foot-squar sealing pylons (two)

9.20 4-mil polyethylene ground cover (8 rolls)

9.21 Spring scale (0 - 50 pound capacity) (one)

9.22 Balloon fabricators tool kit (one)

9.23 Electronics technician tool kit (one)

9.24 C-1 solvent (1 gallon)

9.25 Cleaning rags (1 box)

9.26 Extension cord, 110 V (200 feet)

9.27 Extension cord, 220 V s phase (150 feet)

9.28 Polyethylene pressure sensitive tape (3/4 inch wide) (4 rolls)

9.29 GT-200 adhesive and brush (1 quart container)

9.30 Shipping box for sphere (one)

9.31 Walkie-Talkie radios (three)

9.32 Bull horns (two)

9.33 250-pound test nylon line (3,000 feet)

9.34 500-pound test nylon line (1,000 feet)

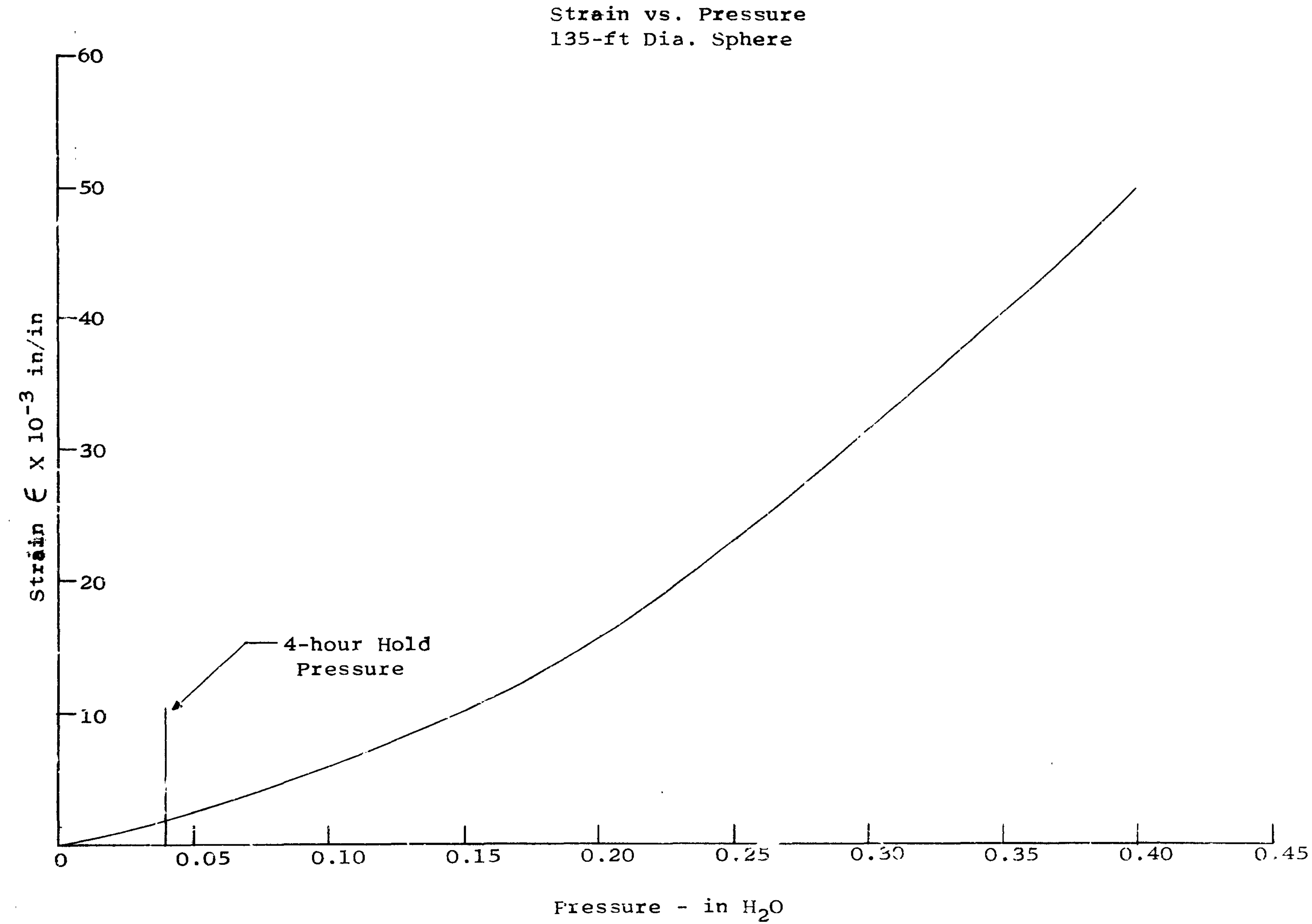
9.35 Nylon nets (one)

9.36 Photo equipment - cameras, film, supplies

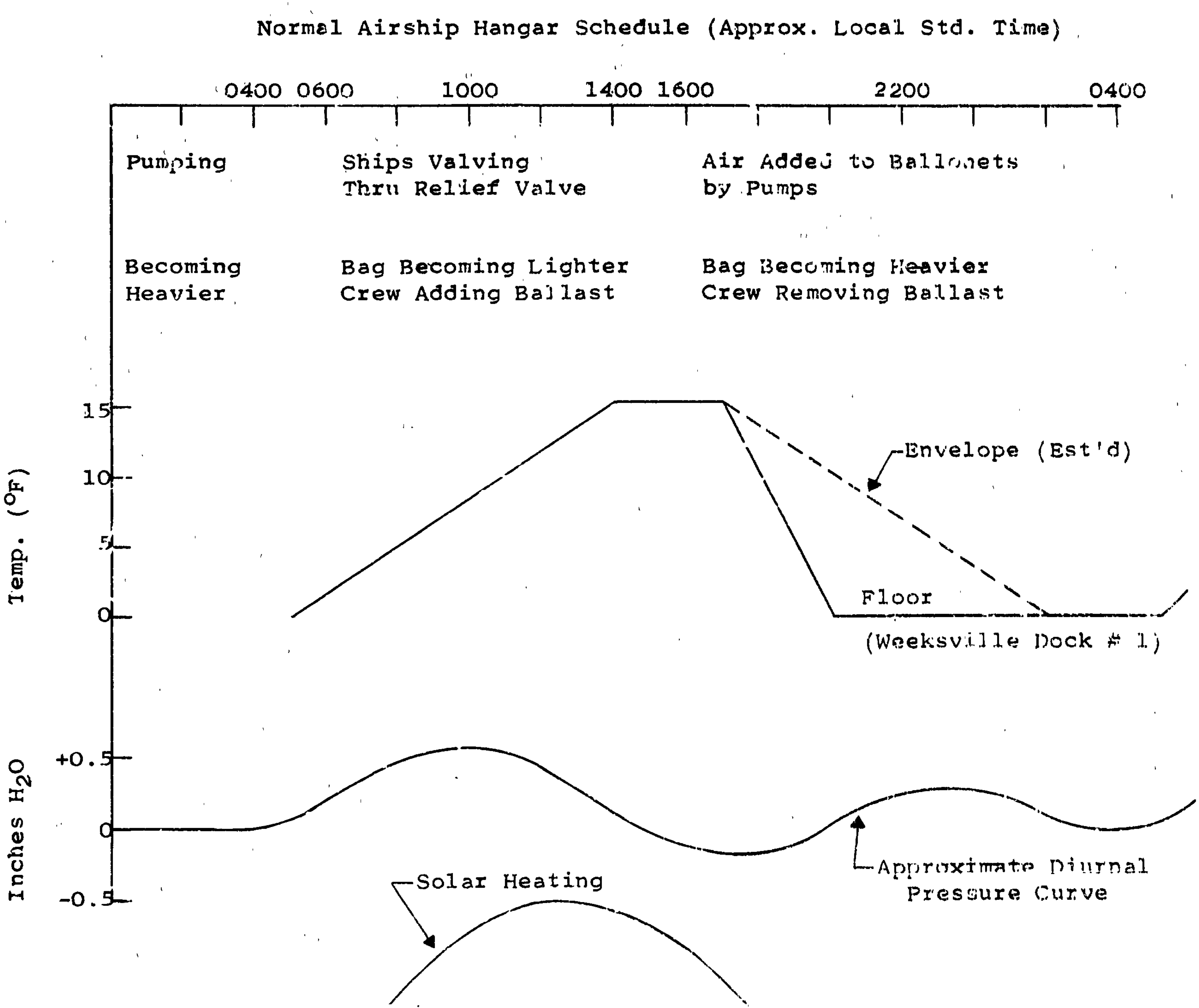
9.37 100 cfm fan (one)

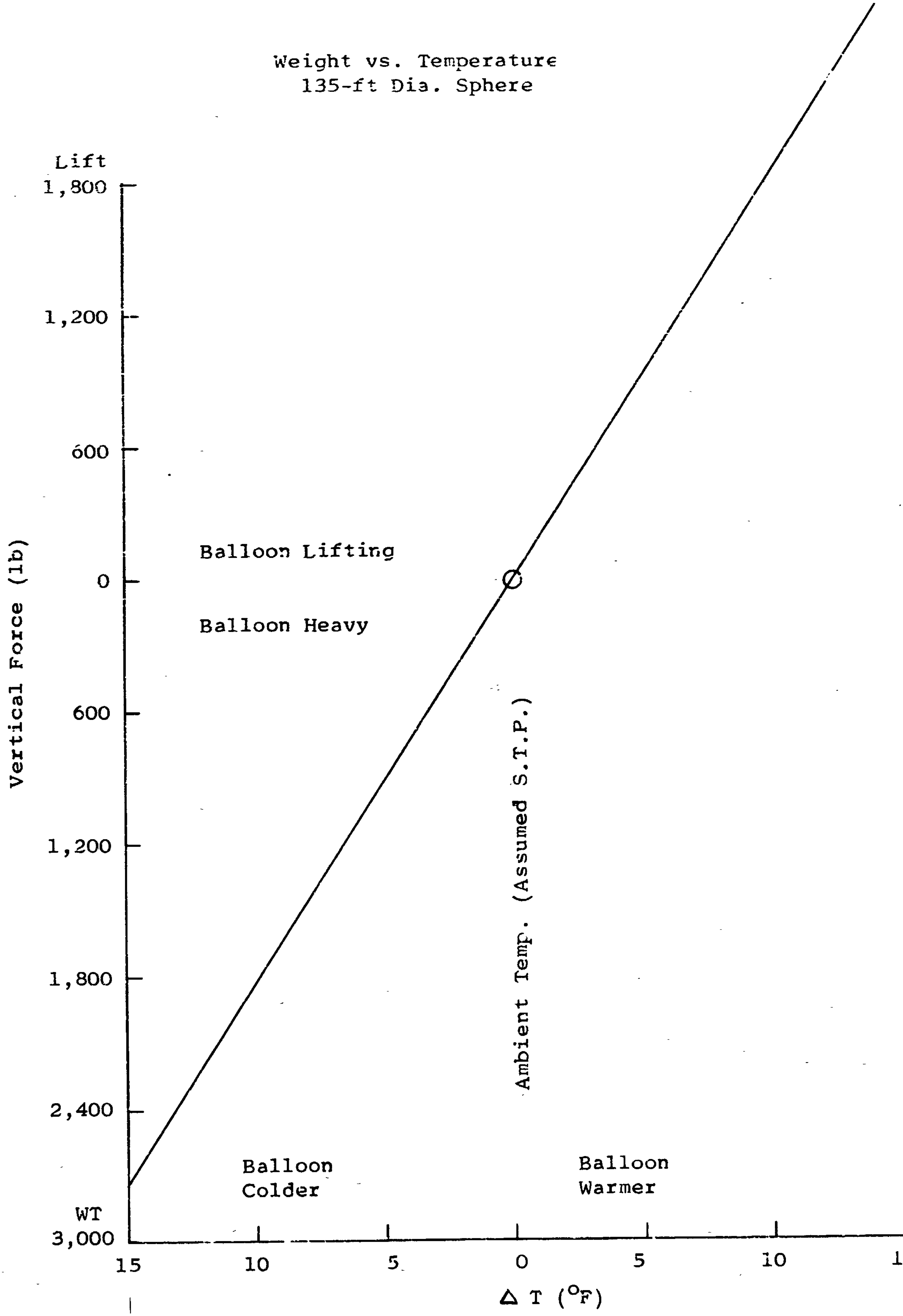
9.38 100-foot steel tape (one)

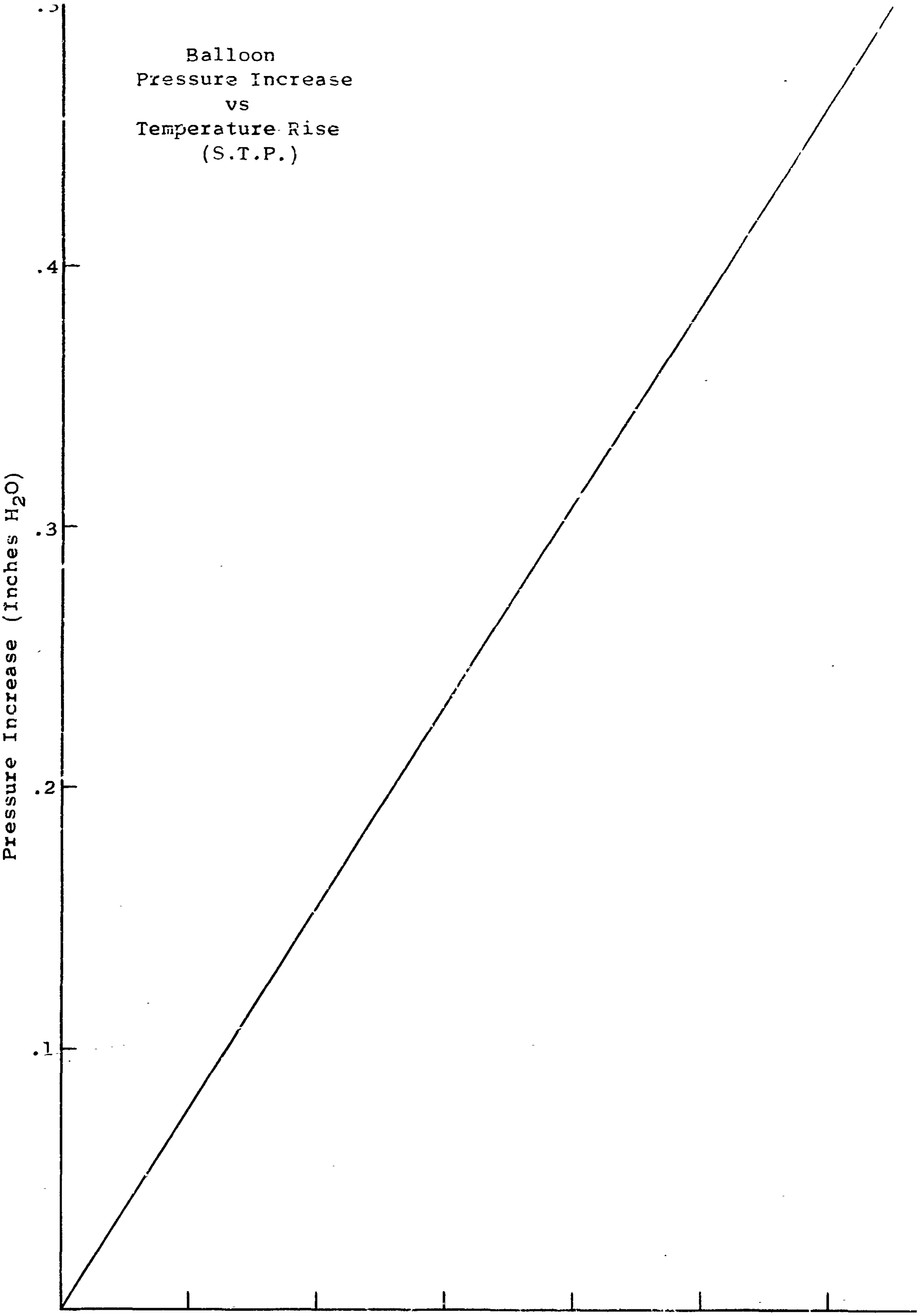
9.39 Vinyl boots (8 pair)



Strain vs. Pressure
135-ft Dia. Sphere
4-hour Hold Pressure
Strain ϵ X 10^{-3} in/in
Pressure - in H_2O
0
10
20
30
40
50
60
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45


Normal Airship Hangar Schedule (Approx. Local Std. Time)
0400 0600
1000
1400 1600
2200
0400
Pumping
Ships Valving Thru Relief Valve
Air Added to Ballonets by Pumps
Becoming Heavier
Bag Becoming Lighter Crew Adding Ballast
Bag Becoming Heavier Crew Removing Ballast
Temp. (°F)
15
10
5
0
Envelope (Est'd)
Floor
(Weeksville Dock # 1)
Inches H_2O
+0.5
0
-0.5
Solar Heating
Approximate Diurnal Pressure Curve


Weight vs. Temperature
135-ft Dia. Sphere
Lift
1,800
1,200
600
0
600
1,200
1,800
2,400
WT
3,000
Vertical Force (lb)
Balloon Lifting
Balloon Heavy
Ambient Temp. (Assumed S.T.P.)
Balloon Colder
Balloon Warmer
15
10
5
0
5
10
Δ T (°F)



Balloon
Pressure Increase
vs
Temperature Rise
(S.T.P.)
Pressure Increase (Inches H_2O)
.5
.4
.3
.2
.1

APPENDIX II

SPECIFICATIONS AND DRAWINGS

DESCRIPTION OF LAMINATION

SPECIFICATIONS FOR X-32-F - HEXAGON PATTERN SPHERE

1. RAW MATERIAL

   1.1 K-11-8 - 0.4-mil 1145 temper O alloy aluminum foil Foil is purchased in 2 widths. Use wide foil on 1st side and narrower foil on second side.

   1.2 M-2-3 - 0.45-mil corona-treated both sides, biaxially oriented polypropylene film.

   1.3 GT-301 adhesive.

2. ADHESIVE PREPARATION

   2.1 Prepare solution of approximately 16% solids.

3. LAMINATION MACHINE PREPARATION AND OPERATING CONDITIONS

   3.1 Check all resin containers, mixers and coating reservoirs to be used in operation for cleanliness. No adhesive residue or contaminants shall be allowed in same.

   3.2 All laminator rolls, idlers and coating rolls are to be clean.

   3.3 Control Settings.

      a. Hot roll - 315 F $\pm$ 5 F
      b. Speed - 12 fpm +
      c. Hot roll pressures - Firm enough to achieve complete lamination. Reference on vernier scale. Record readings and maintain pressure.
      d. Draw pressure, rewind tension Mount Hope roll and idlers to be set to achieve firm, wrinkle-free rolls.
      e. Slit to width required on order.
      f. Coat dull side of aluminum foil. Brake on unwind roll shall be set at 15 to 40 ft-lb drag for a full roll and decreased to approximately 15 as roll size diminishes.
      g. Use same conditions for laminating second side. Coat foil and laminate polypropylene side of first lamination.
      h. A square yard sample of the lamination shall weigh 60

to 49 grams. Laminations outside of weight tolerance are subject for rejection.

4. PROCEDURE, INSPECTION, RECORDING, SAMPLING

4.1 Length of rolls shall be 4000 ft minimum except where conditions of material makes shorter rolls necessary

4.2 A sample of one running yard from the beginning and end of each GTS roll shall be taken labeled with roll number and forwarded to the chemistry laboratory for testing

4.3 One square yard shall also be taken at the beginning and end of each roll for immediate weight sampling

4.4 A minimum of four times per hour the technician shall make solids content measurement on the adhesive and record on GTS Form 61.98. Continuous readings shall also be made and recorded on: time, coating wheel speed, adhesive lots, web speed, hot roll temperature, room temperature, humidity, draw roll pressure, rewind tension, hot roll pressure, laminate gage.

4.5 One technician will be stationed full time at coating roller for 100% inspection of coating of foil. Duties include calling for necessary adjustments to keep material free and coating evenly.

4.6 One technician shall be stationed by polypropylene unwind to maintain even alignment of film and foil as it enters laminator rolls.

4.7 One technician shall be stationed at the rewind station to 100% visually inspect material coming out of laminator towards rewind roll. Any and all defective areas shall be flagged by attaching a small piece of red poly (M-3) tape on the edge of roll (no further than 1/2 inch into roll from edge). Defect areas shall be defined as:

a. Fine wrinkles, comparable to hairline in size, shall not be considered a defect although it is desirable to eliminate them. Wrinkles that have fullness causing an actual pleat or fold shall be noted on GTS Form 60.71, flagged and the laminator immediately adjusted for elimination.

b. Holes and tears (rips) shall also be flagged.

c. Stretch Marks -- Fracture of the foil in the transverse direction has a characteristic appearance and is easily identified. At first sign of such stretching an adjustment is indicated in the draw rolls. The technician's duties also include preventing wrinkles from entering the rewind roll by proper adjustment of roller. He shall also observe rewinding of salvage rolls from slitter so that scrap edges do not enter the center rewind roll.

4.8 All inspection records, (foil certification, polypropylene certification, polypropylene Inspection Record, GTS Form 60.71, lamination inspection, record on GTS Form 60.71, Lamination Quality Control Sheet, and Laboratory Report on GTS Roll No.) shall be turned over to the Project Leader for placement in Record Notebook.

4.9 All rolls of foil, first run laminate and completed laminate shall be sotred or handled horizontally and suspended by each end of the steel core or by a shaft through the steel core. The roll should never be placed on floor or table with weight of roll bearing on laminated material. The cradle support on the transfer cart is also an approved handling method, in addition to supporting by the core ends.

4.10 Each roll laminated will have a GTS number assigned and have the identification label on both inside of core and outside of roll. A record sheet, GTS Form 61.97 shall contain GTS roll no., aluminum foil mill roll number, Udel mill roll number, total number of feet in roll, core weight, gross weight, and net weight.

4.11 Make <u>all</u> splices of film, foil and laminate butt splices with high temperatures masking tape on both sides.

4.12 Make rolls approximately 5000 ft long.

4.13 Use 56-in steel cores with a 1/4-in notch on each end.

4.14 Web must be 53 in $\pm$ 0.25 in wide.

4.15 Attach a copy of inspection sheet and flag record to each roll.

4.16 Remove all single sided laminations.

4.17 Pack in wooden pallets or boxes suspended on dowels and pad ends of rolls so that they are not telescoped or bruised in shipping.

4.18 There must be no wrinkles, tears, or fold-overs on edges of the web, and edge must not be distorted.

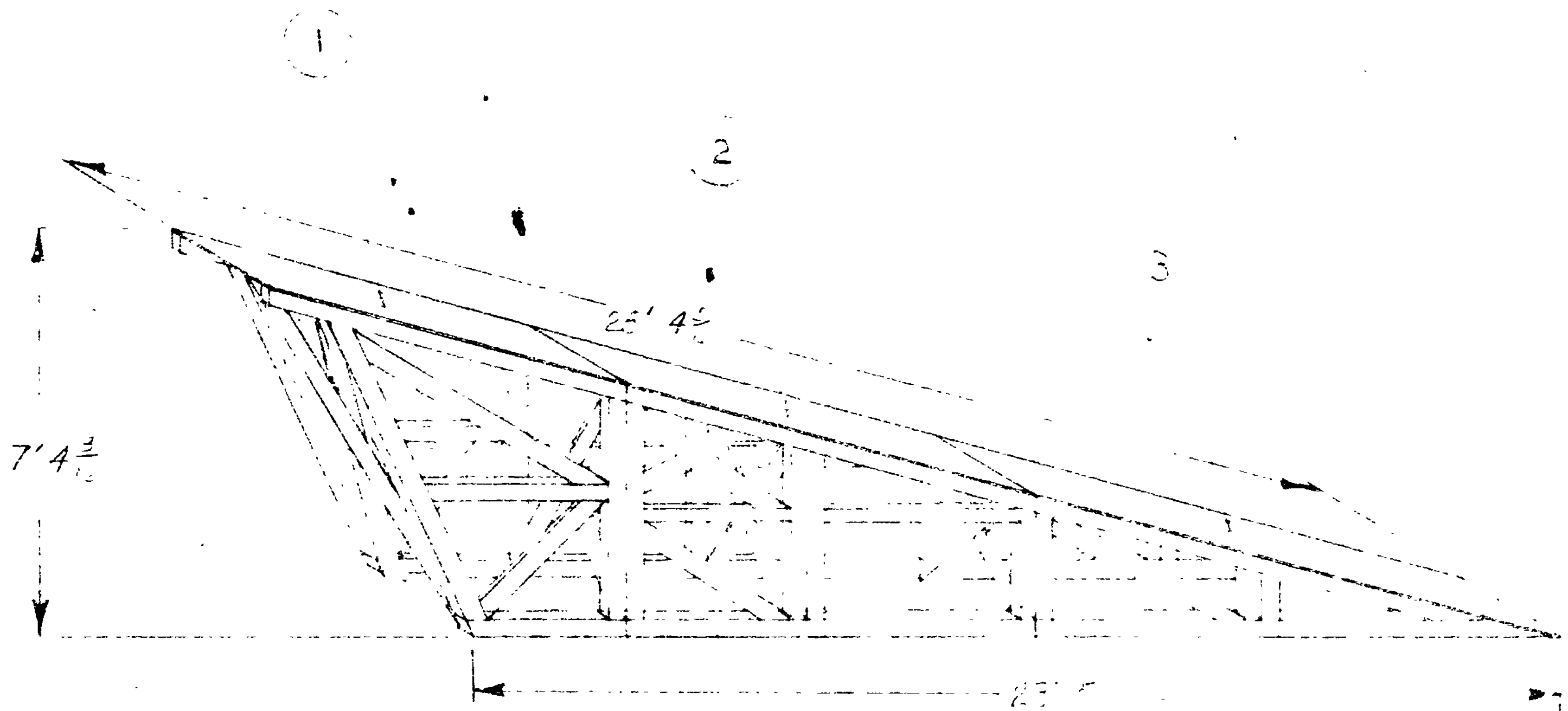
5. TESTING

5.1 Tensile tests shall be performed on the samples taken in procedure 4.2. Two specimens from the center and two specimens from the edge of each sample shall be cut in the transverse direction. Each specimen shall be 1 in wide and free of cracks, notches, and other defects. Instron shall be set at CH .02 in/minus CS 1.0 in/minus jaw spread 5 in and test temperature 25 C. Tensile shall be 20,000 psi minimum.

5.2 One specimen from the center and edge of the samples, will be taken in the transverse direction for a thermal cycle test. The test will consist of running each specimen 180 degrees around a 1/2-inch diameter dowel while submerged in boiling water and then in liquid nitrogen. The cycle will be completed 10 times without signs of delamination.

5.3 Specimens from the center and edge of the sample will be taken for the Scotch tape test. The tape test will consist of rapidly stripping a piece of Scotch tape, three inches long, and one-half to one inch wide from the surface of the specimen. There shall be no evidence of delamination.

		T953		[illegible] RAMP SE[illegible] #1
	2	T95[illegible]		[illegible] RAMP SE[illegible] #2
	3	T95[illegible]		[illegible] #3
NOT SH[illegible]	4		6	[illegible] ½" CARRIAGE BOLT



G. S. NUMBER	DATE	REV. LETTER	FORMERLY	DATE	ENT.	CHECK

TOLERANCES UNLESS OTHERWISE NOTED: FRACTIONAL ± 1/64 DECIMAL ± .005 ANGULAR ½°

REMOVE ALL SHARP EDGES

ASSEMBLY NO. | NO. REQ'D

MATERIAL: SEE B/M

SCALE: ¼" = 1' 21645-19

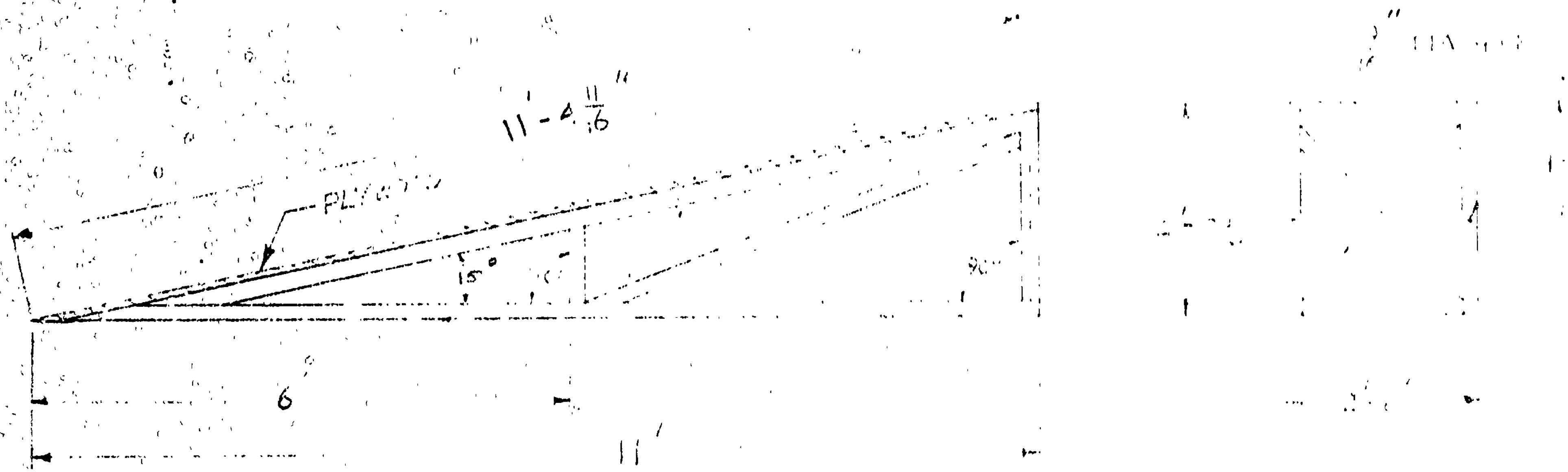
PROJECT | DRAWN | CHECK | CERTIFY

TITLE: LOADING RAMP ASS'Y

SCHJELDAHL COMPANY
NORTHFIELD, MINNESOTA

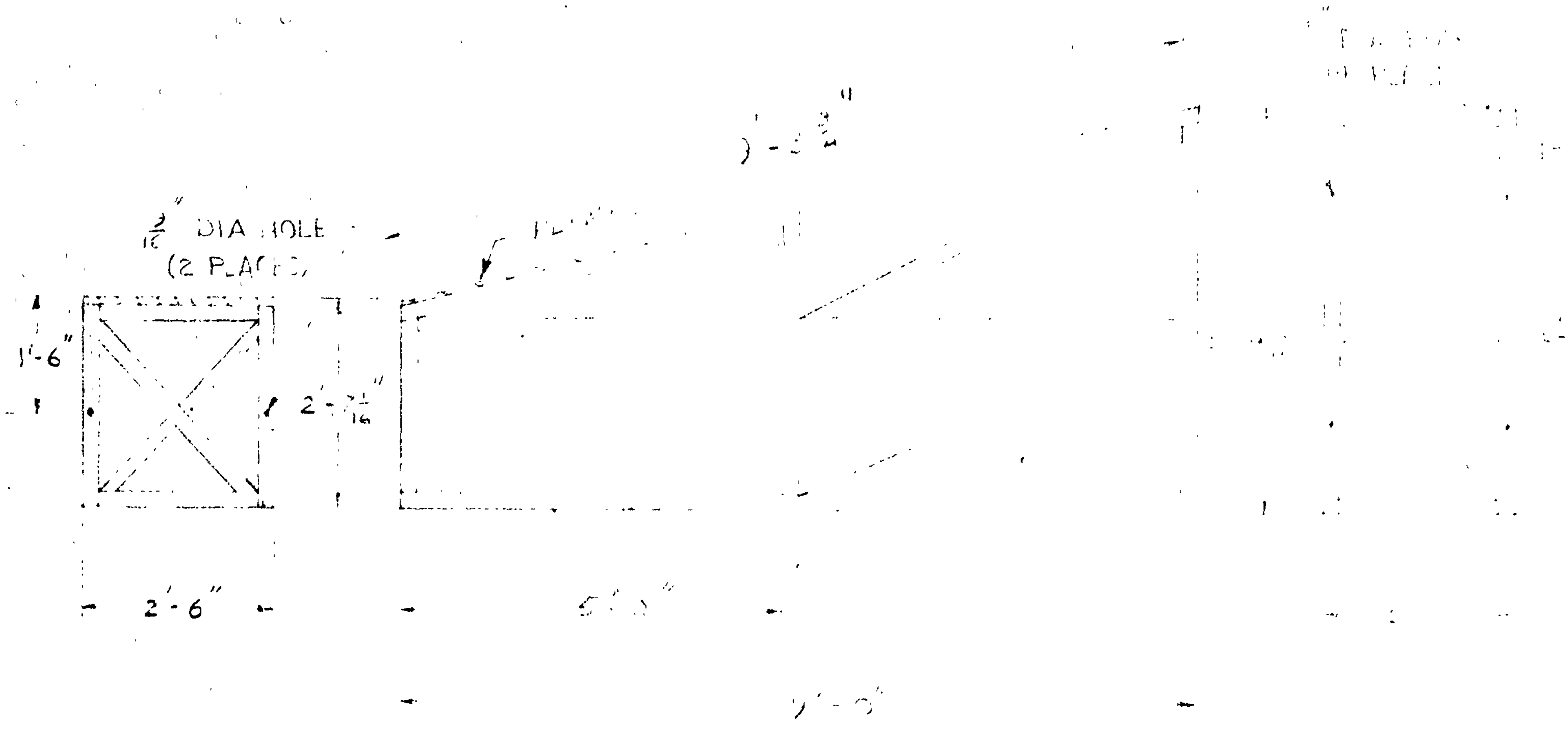
DRAWING IDENTIFICATION — SIZE: B — NUMBER: T952 — REV.

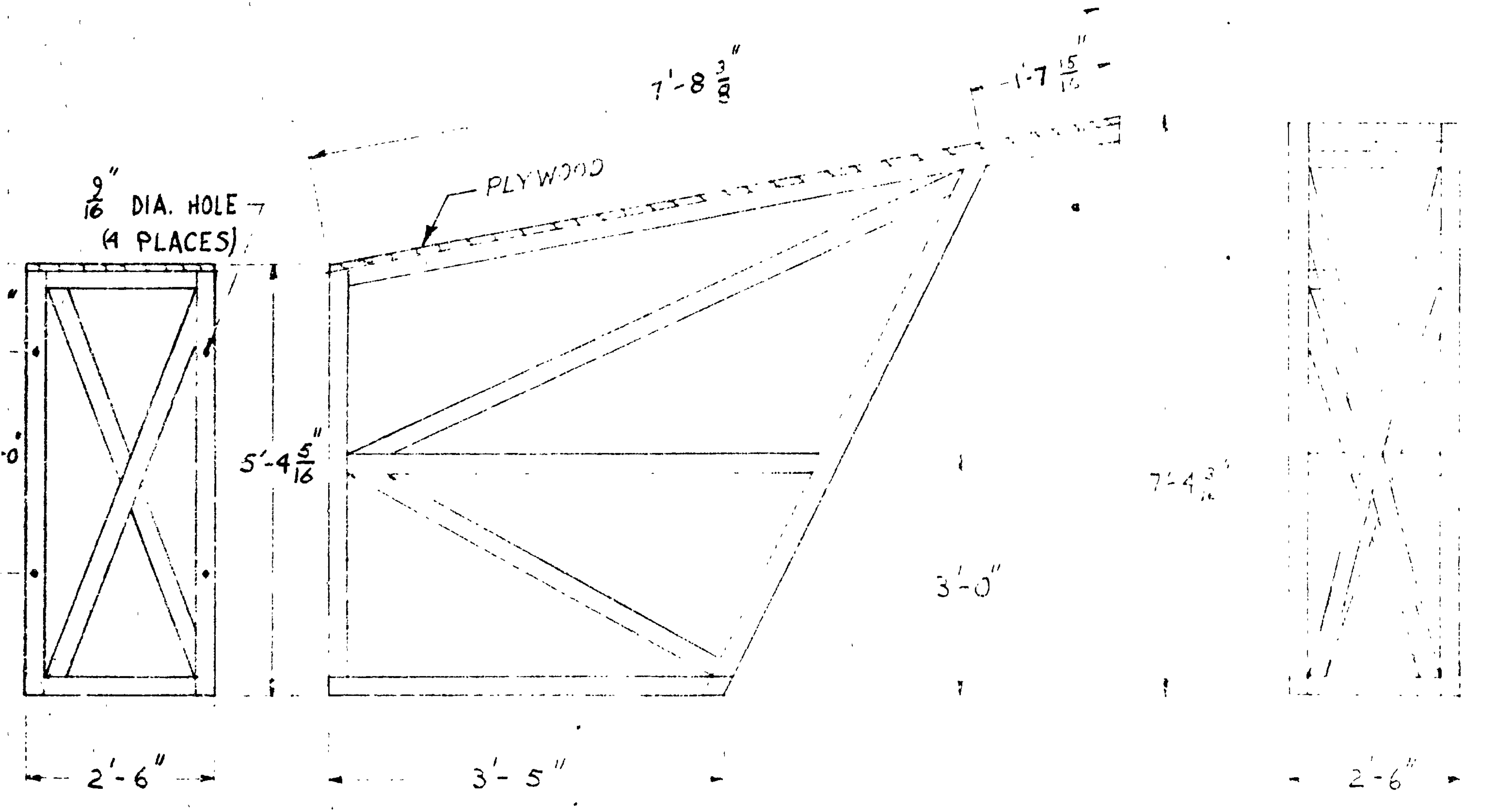
NON STANDARD DRAWING
G. T. SCHJELDAHL CO. USE ONLY



LOADING RAMP

G. T. SCHJELDAHL



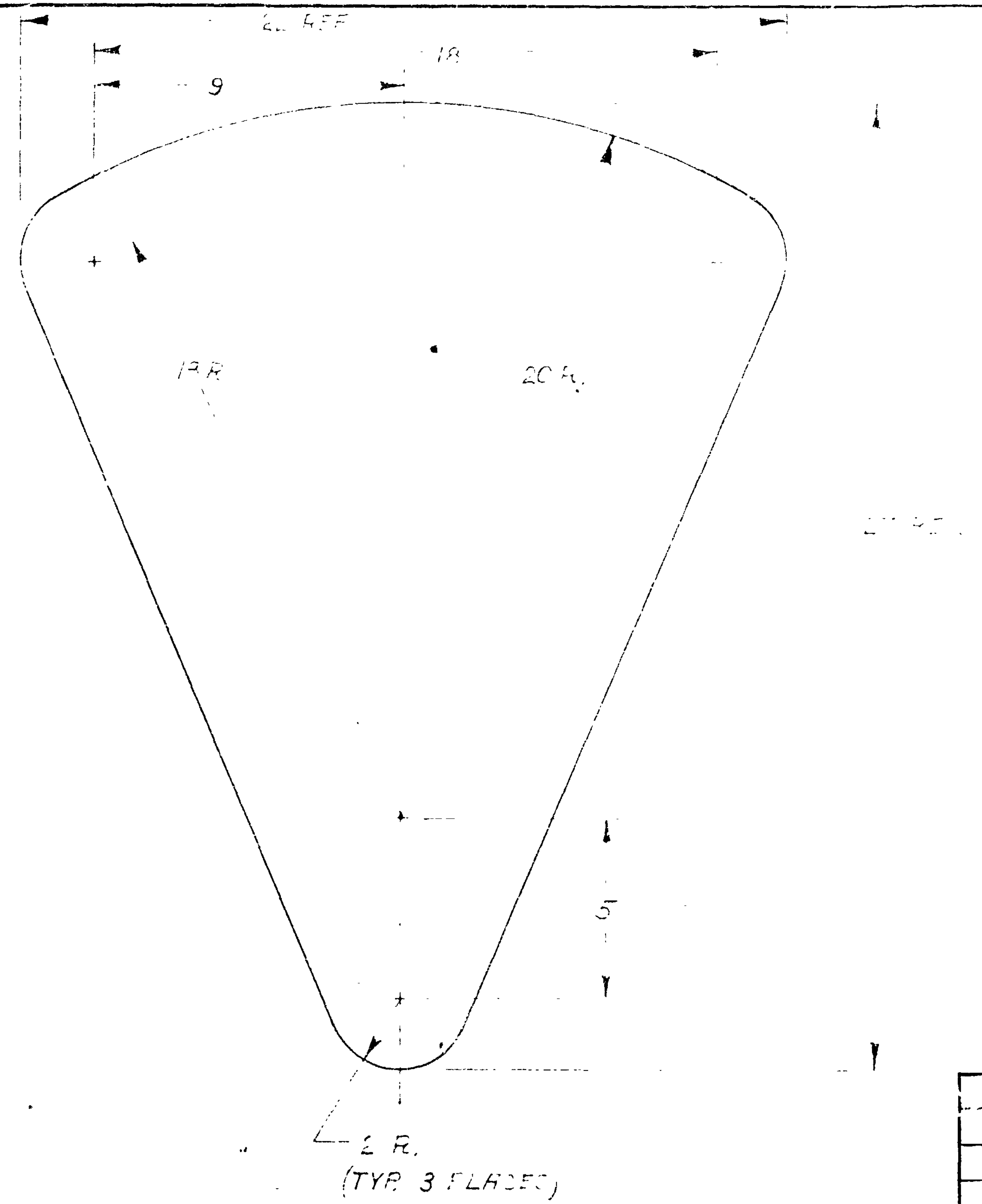


CHECK
CERTIFY

MAT'L 2×4" PINE & 1/2" PINE PLYWOOD

LOADING RAMP, SECTION 3

NON STANDARD DRAWING
G. T. SCHJELDAHL CO. USE ONLY



C. S. NUMBER	DATE	REV. LETTER	FORMERLY	DATE	ENIT.	CHECK

TOLERANCES UNLESS OTHERWISE NOTED: FRACTIONAL ± 1/4 DECIMAL ± .005 ANGULAR ½°

REMOVE ALL SHARP EDGES

ASSEMBLY NO.	NO. REQ'D
C1001604	1

MATERIAL: F-3-3

SCALE: 1/4 : 1 | 21645

PROJECT / DRAWN / CHECK / CERTIFY

TITLE: NYLON PATCH SMALL

SCHJELDAHL COMPANY
NORTHFIELD, MINNESOTA

DRAWING IDENTIFICATION — SIZE: B — NUMBER: 1001603 — REV.

APPENDIX III

FINANCIAL REPORT

Labor	$ 54,402.31
Burden	96,790.04
Materials	68,202.03
Subtotal	$219,394.38
G & A	25,093.33
Subtotal	$244,487.71
Fee	10,725.00
Subtotal	$255,212.71
Proprietary Items	.48
Grand Total	$255,213.19

This final figure is dependent upon the establishment of the burden and G & A rates for the periods of 8/1/63 through 2/29/64 and 3/1/64 through 9/30/64.